TFAWS Interdisciplinary Paper Session

Interactive LUROVA™ Thermal Model for the STEM Simulation Game

Presented By

Ron Creel

Retired Apollo Lunar Roving Vehicle Team Member

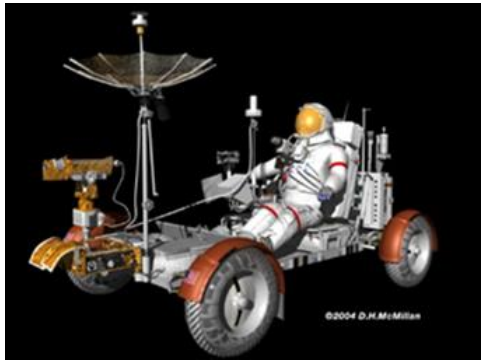
Thermal & Fluids Analysis Workshop
TFAWS 2017
August 21-25, 2017
NASA Marshall Space Flight Center
Huntsville, AL

THERMAL & FLUIDS ANALYSIS WORKSHOP

TFAWS
MSFC • 2017

Outline

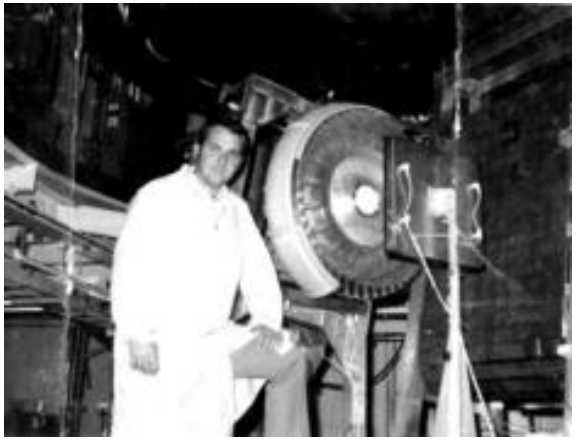
- Apollo Lunar Rover Thermal Modeling for Mission Support
- LUROVA™ Thermal Modeling for TFAWS
- LUROVA™ Simulation Game for STEM



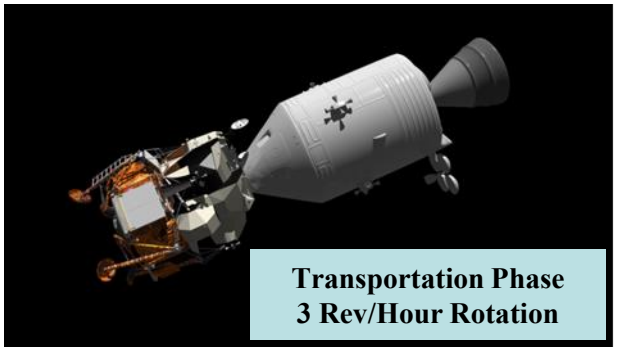
- Interactive LUROVA™ Simulation Game Thermal Model
- Verification / Correlation of the LUROVA™ Sim Game Model
- Future Plans for the LUROVA™ Simulation Game
- LUROVA™ Poster and Demonstration for Attendees

Apollo Lunar Rover Thermal Testing / Modeling

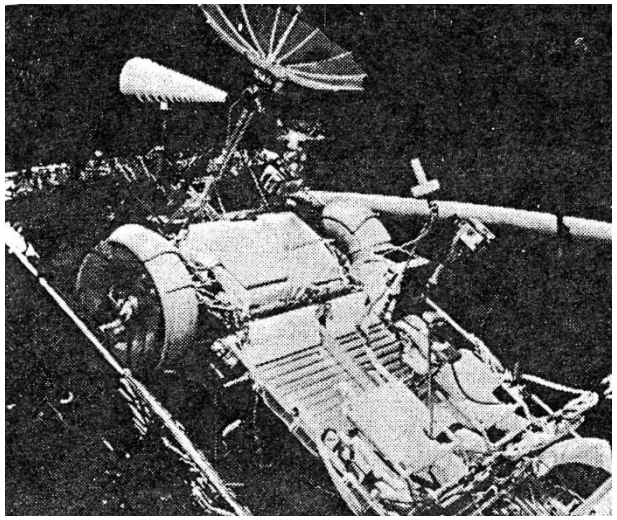
- Test Correlated Thermal Models Were Vital for Rover Success



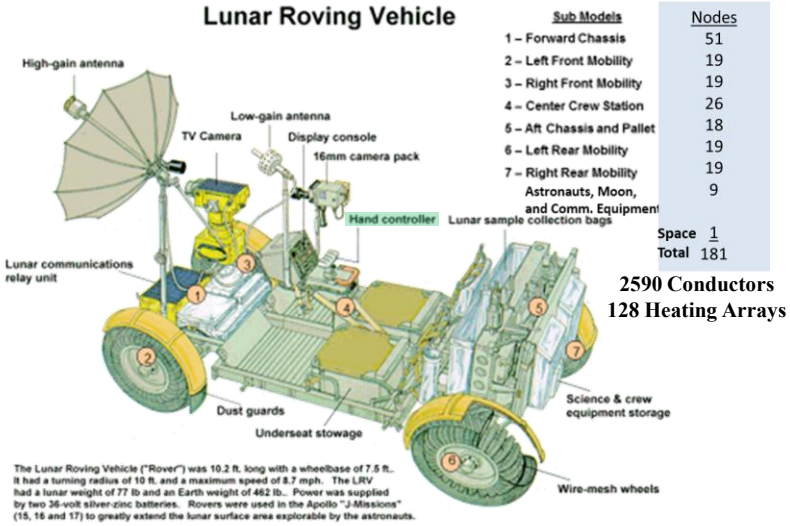
Ron Creel with Rover Mobility TVAC Test Unit



Folded Rover Modeled, but not Tested



Qualification and Flight Units TVAC

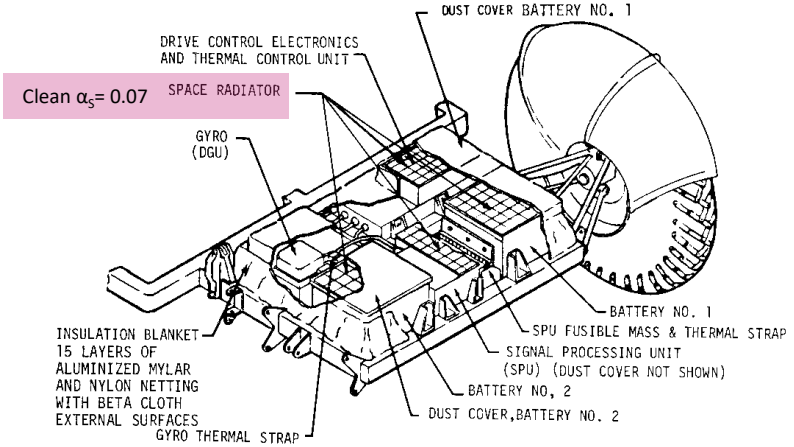


Sub Models	Nodes
1 – Forward Chassis	51
2 – Left Front Mobility	19
3 – Right Front Mobility	19
4 – Center Crew Station	26
5 – Aft Chassis and Pallet	18
6 – Left Rear Mobility	19
7 – Right Rear Mobility	19
Astronauts, Moon, and Comm. Equipment	9
Space	1
Total	181

2590 Conductors
128 Heating Arrays

181 Node SINDA Thermal Model for Apollo 15

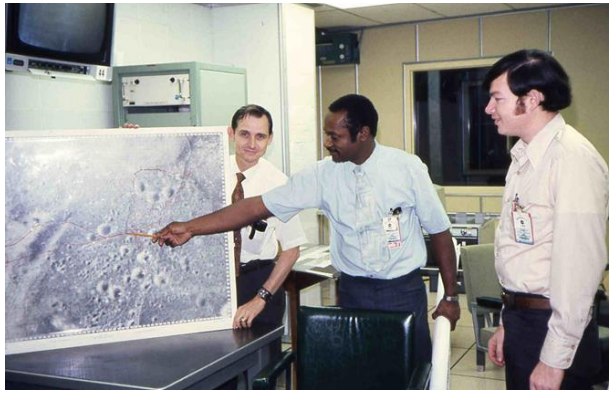
Astronaut Silver Snoopy Awarded for Thermal Modeling after Apollo 16 in July, 1972



19 Node Forward Chassis Thermal Model for Apollo 16 and 17

LUROVA™ Simulation for Apollo Mission Support

- **LU**nar **ROV**ing **A**dventures - **LUROVA™** for Apollo 15, 16, 17



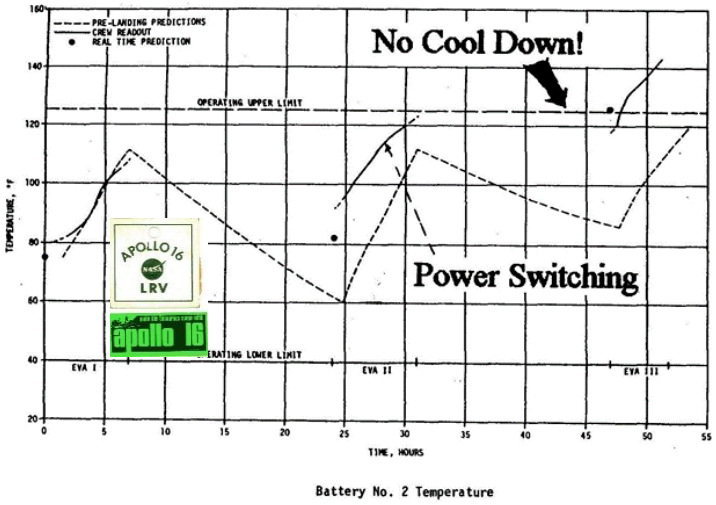
20 Meter Resolution Terrain Data

LRV-3 REAL-TIME THERMAL ANALYZER
INPUT MODE

ACTUAL DATA	**********		
BEG DRIVE	_____	EVA TIME	_____
SEG DIST	_____	OUT TIME	_____
NAV ON	_____	LCRU ON	_____
BAT1 AMPHR	_____	BAT2 AMPHR	_____
BAT1 TEMP	_____	BAT2 TEMP	_____
STATUS	_____	COOLDOWN	_____
SUN ANGLE	_____	HEADING	_____
ALP B1+SPU	_____	ALP B2+DCE	_____
LM DIST	_____	LM TEMP	_____
LTX	_____	UTX	_____
LTY	_____	UTY	_____
COMPUTED DATA	**********		
BAT1 TEMP	_____	BAT2 TEMP	_____
SPU TEMP	_____	DGU TEMP	_____
DCE TEMP	_____	SPU WX MLT	_____
DCE WX MLT	_____	RAIL TEMP	_____

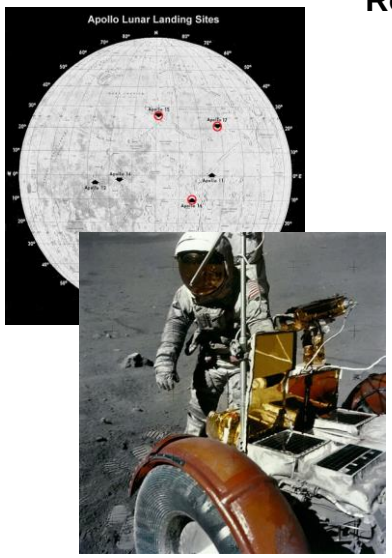
19 Node Thermal Model Input (Replaced Cumbersome and Slow 181 Node Model)

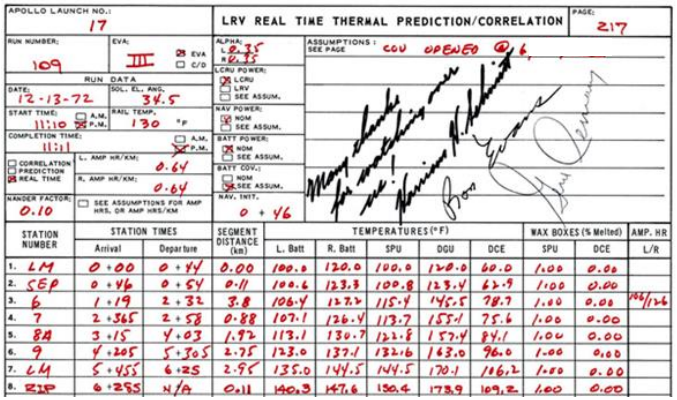
Ron at LUROVA™ Thermal Model Control Console



Battery No. 2 Temperature

Dust Coverage Degradation Effects Modeled

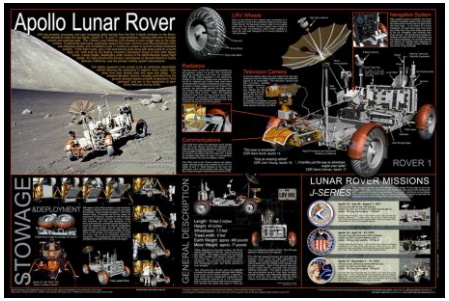




Astronauts Appreciated Timely and Accurate Thermal Modeling

LUROVA™ Thermal Modeling for TFAWS

- **2006** – Presented Apollo Lunar Roving Vehicle mission performance and lessons learned, and introduced Rover mission support thermal models
  - Thermal models originally planned for CD to accompany retrospective book
  - 19 Node model then used for NASA Nightrover Power Storage Challenge
- **2014** – 181 node SINDA thermal model updated with render engine provided external surfaces for radiation conductors and solar heating
  - Conductors and solar heating needed to add to historical SINDA model nodes listing
  - 911,509 poster polygons reduced to 7805 polygons for TRASYS surface modeling



- **2017** – **LUROVA™** thermal model incorporated in a **Science, Technology, Engineering, and Mathematics (STEM)** simulation game for interactive student challenge and Moon exploration experience
  - Trademark purchased for **LUROVA™** Simulation Game
  - Initial game structure contributed by Computer Science associate professor and students at the University of Alabama in Huntsville (UAH)
  - Exploration realism is improved by interactive use of actual lunar terrain data collected since 2009 by NASA Lunar Reconnaissance Orbiter (LRO) spacecraft

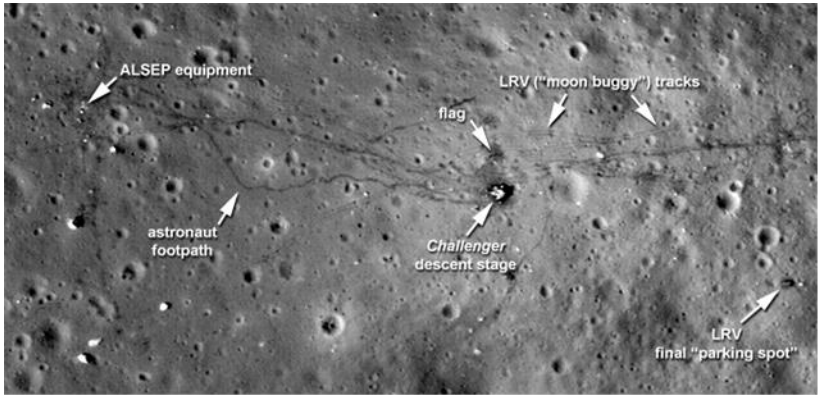
LUROVA™ Simulation Game for STEM

- "Simulation Game = Attempt to copy various activities from real life in the form of a game for education, training, analysis, or prediction."

LUROVA™ STEM Simulation Game Provides Apollo Mission Support Thermal Model with High Resolution Surface Model and LRO Terrain Data

Variable Planning and Preparation for Mission Timing, Location, and Rover Configuration
Hand Controller for Driving and Steering
Battery Power Usage and Solar Heating
Component Failures and Cooldown Dust Effects

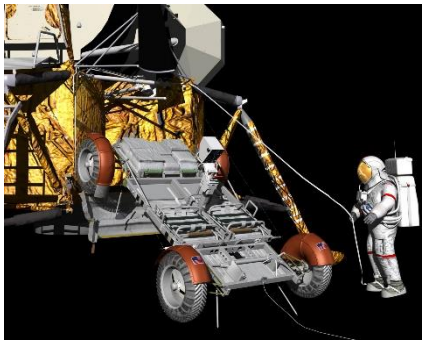
Lunar Reconnaissance Orbiter (LRO) Collecting 0.5 Meter Resolution Terrain Data Since 2009



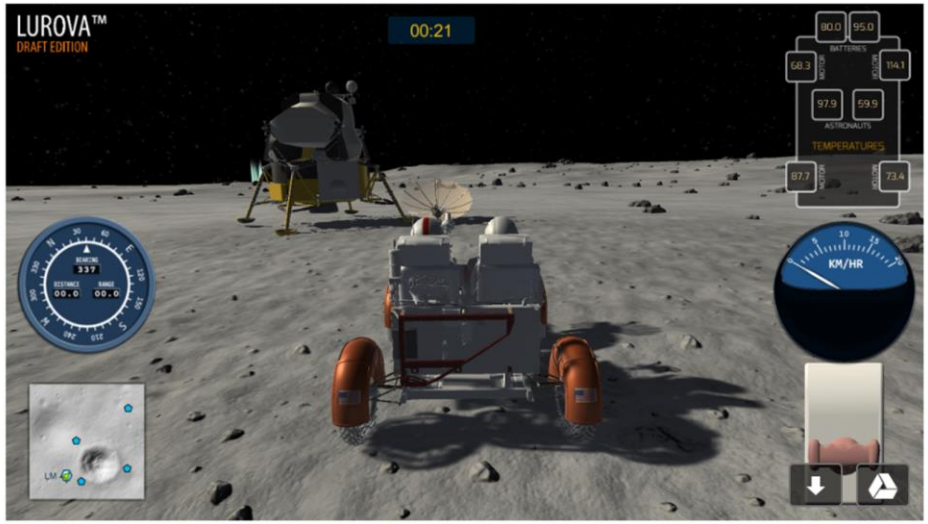
LRO Terrain Data for Apollo 17

Interactive LUROVA™ Simulation Game Play

- Adventurer Plans and Executes Exploration Traverses, and Views:
  - Computed Position, Heading, Speed, Slope, Power, and Temperature Results

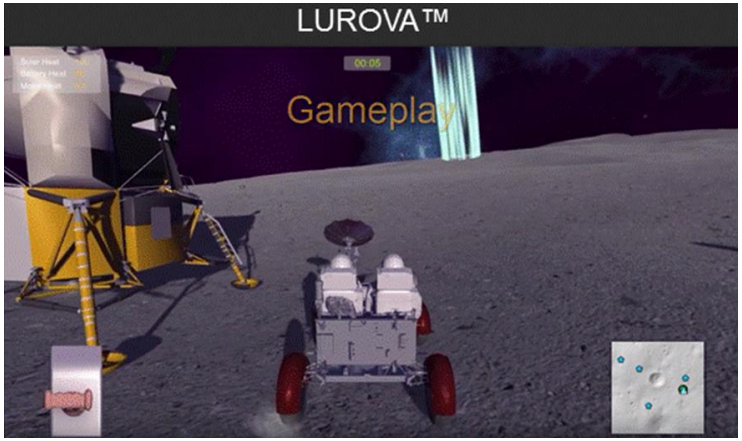


Adventurer Deploys Rover from Lunar Module (LM) and Loads Equipment



Adventurer Views Heading, Speed, and Temperatures

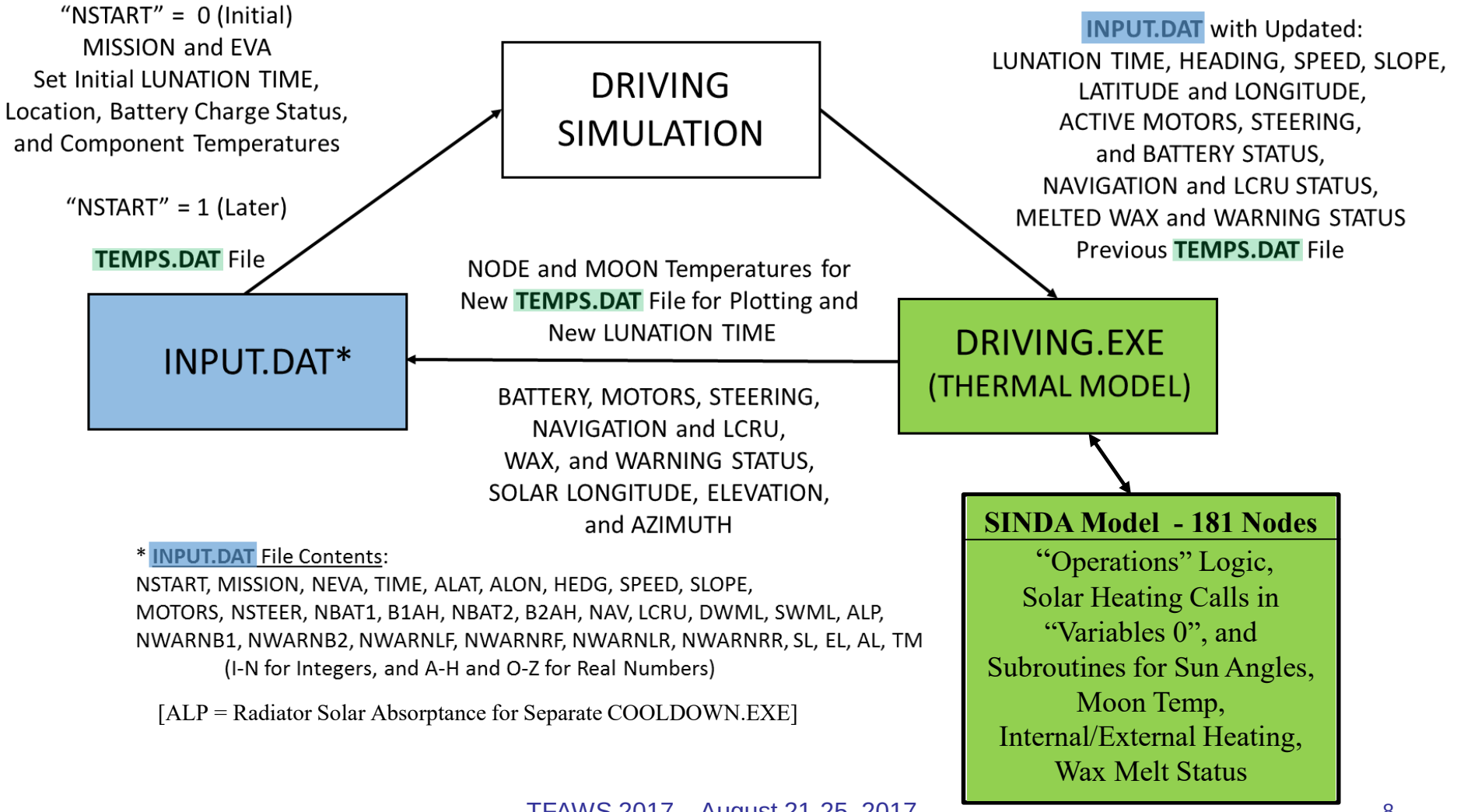
Adventurer Activates Rover Switches and Uses Hand Controller for Driving



Adventurer Drives Rover to Pre-planned Station Stops for Exploration and Sample Collections

Interactive LUROVA™ Sim Game Thermal Model

- Simulation Game Thermal Model Increases STEM Exploration Realism
  - SINDA Provides Responsive Thermal Programming



* INPUT.DAT File Contents:
NSTART, MISSION, NEVA, TIME, ALAT, ALON, HEDG, SPEED, SLOPE,
MOTORS, NSTEER, NBAT1, B1AH, NBAT2, B2AH, NAV, LCRU, DWML, SWML, ALP,
NWARNB1, NWARNB2, NWARNLF, NWARNRF, NWARNLR, NWARNRR, SL, EL, AL, TM
(I-N for Integers, and A-H and O-Z for Real Numbers)

[ALP = Radiator Solar Absorptance for Separate COOLDOWN.EXE]

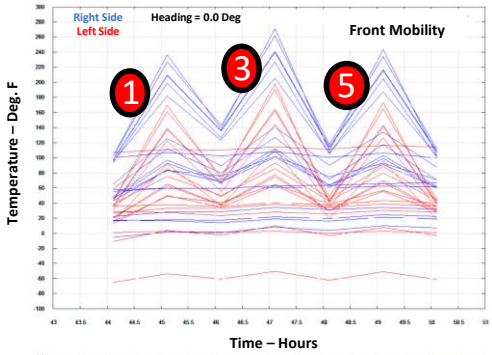
Verification of the LUROVA™ Sim Game Model

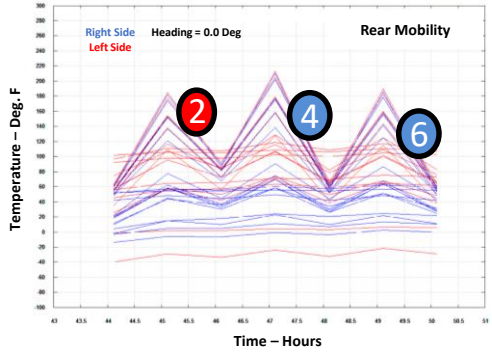
- Simulated Operation During Driving & Cooldown Periods Verified

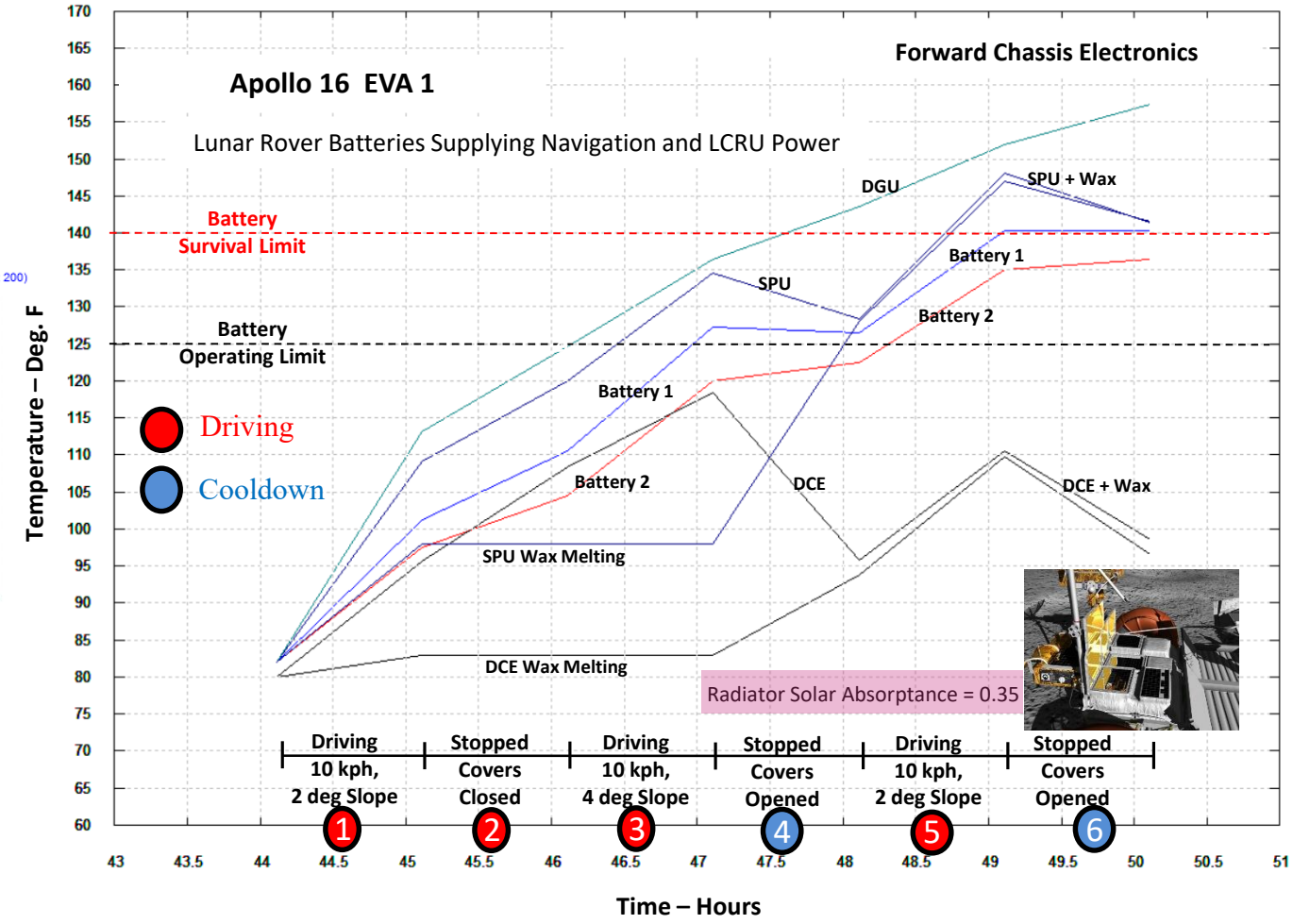
LRV Component Temperature Limits – Deg. F

	Component	Minimum Survival	Minimum Operating	Maximum Operating	Maximum Survival
Electronics	Batteries*	-15	40	125	140
	Signal Processing Unit (SPU)	-65	30	130	185
	Directional Gyro Unit (DGU)	-80	-65	160	200
	Indicating Meters	-22	-22	160	160
	Position Indicator	-65	-22	185	185
	Drive Controller Electronics (DCE)	-20	0	159	180
Mobility	Traction Drive**	-50	-25	400	450
	Suspension Damper	-70	-65	400	450
	Steering Motor	-50	-25	360	400
	Wheel	-250	-200	250	250

Astronauts Read Temperature On Display Panel - * Batteries ** Traction Drive (Start At 200)

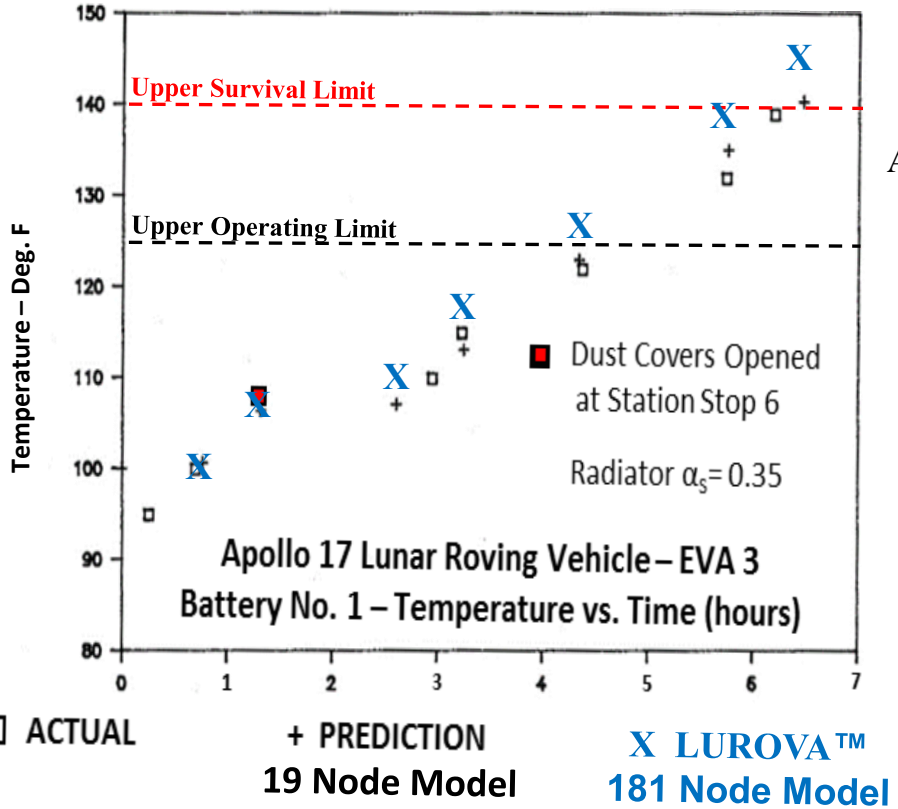






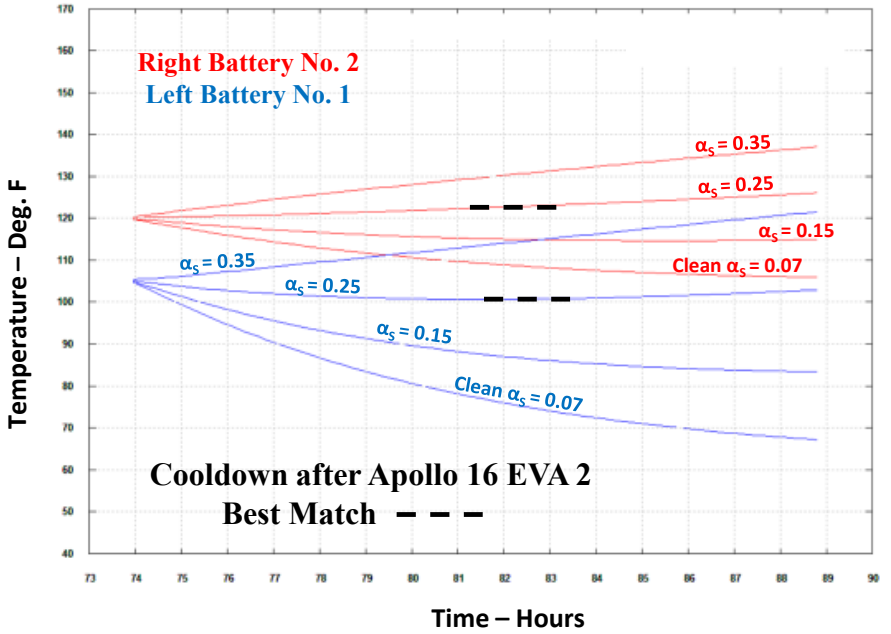
Correlation of the LUROVA™ Sim Game Model

- **LUROVA™ Simulation Game Correlates Well With Last Rover Sortie**
  - Lunar Dust Degradation Effects on Radiators Studied



Apollo Dust Brush

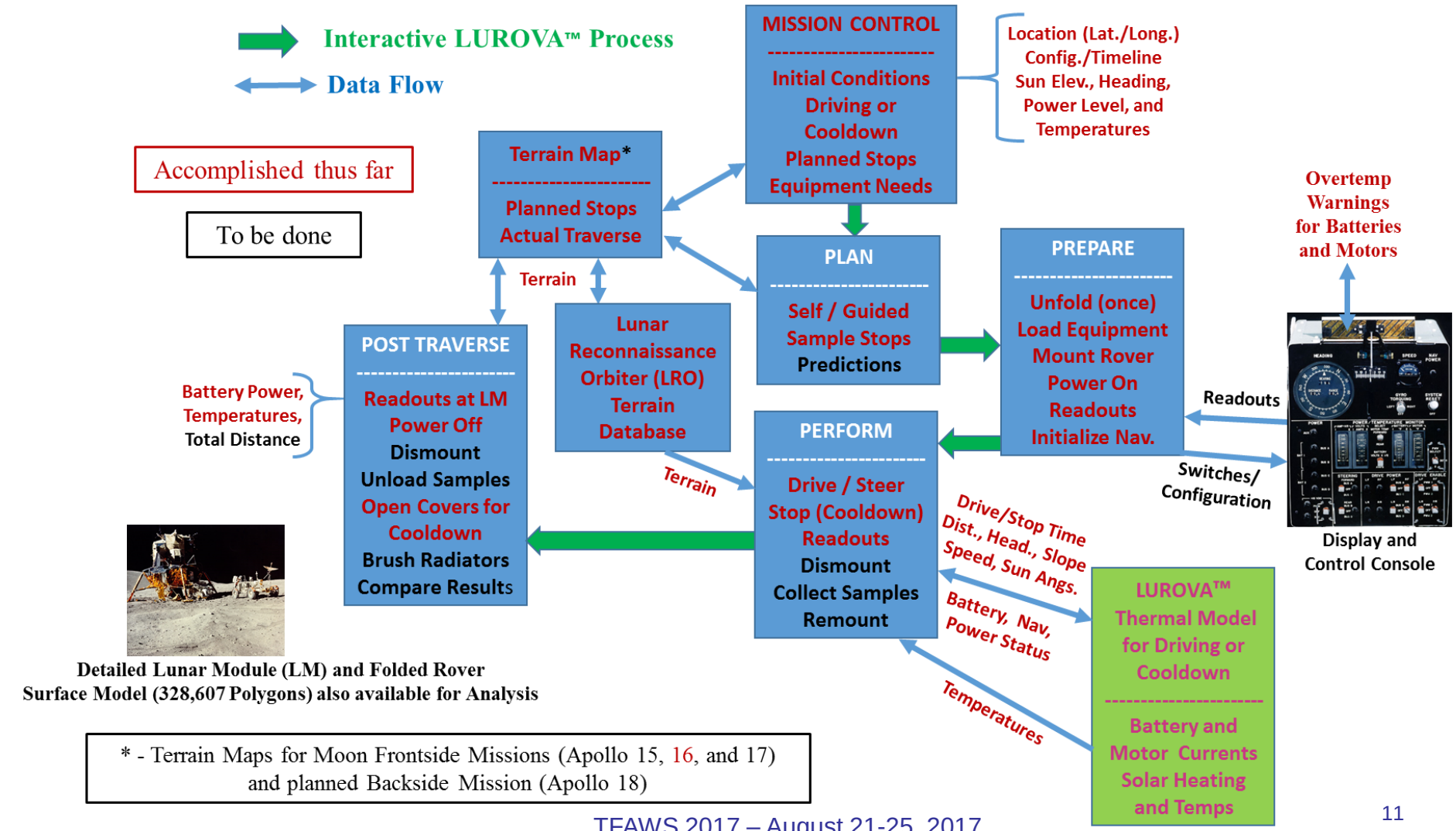
Astronaut Brushing Dust from Radiator



Dust Degradation of Radiator Solar Absorptance - α_s

Future Plans for the LUROVA™ Simulation Game

- Finish Interactive **LUROVA™ STEM** Simulation Game Development
  - Opportunities for Student "Beta Testing" and Expansion for VR, "MAROVA"



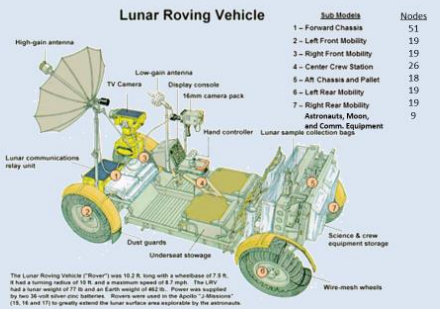
Detailed Lunar Module (LM) and Folded Rover Surface Model (328,607 Polygons) also available for Analysis

* - Terrain Maps for Moon Frontside Missions (Apollo 15, 16, and 17) and planned Backside Mission (Apollo 18)

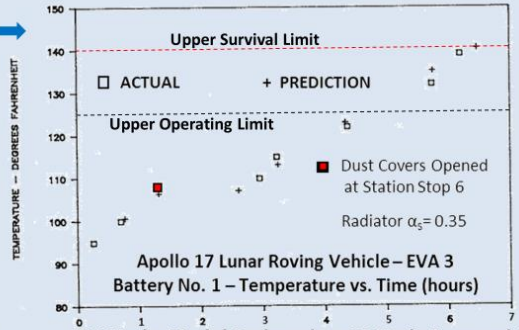
LUROVA™ Poster and Demonstration for Attendees

Interactive LUROVA™ (LUnar ROVing Adventures) Simulation Game Being Developed for Realistic Student STEM Challenge and Moon Exploration Experience

(Contact Ron Creel, Apollo Lunar Roving Vehicle Team Member, at roving.ron@gmail.com for additional technical information)

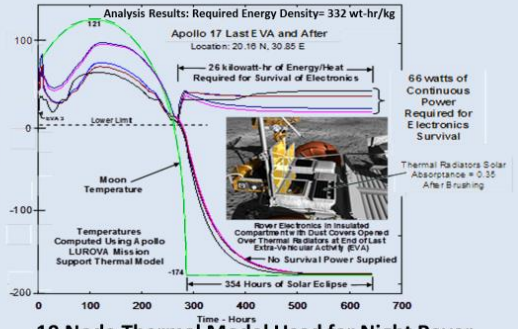


181 Node TVAC Test Correlated NASA Rover SINDA Thermal Model Used for Apollo 15 Mission Support

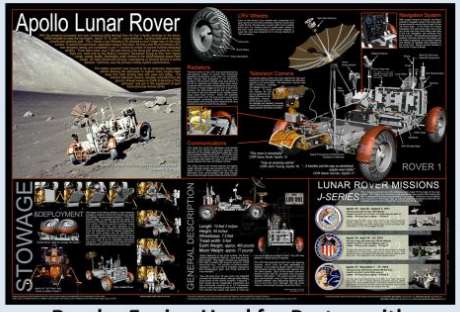


181 Node Model Reduced to 19 Node Forward Chassis Model for Quicker Response to Apollo 16 and 17 Mission Control Needs

Astronaut Silver Snoopy Awarded for LUROVA™ Thermal Modeling

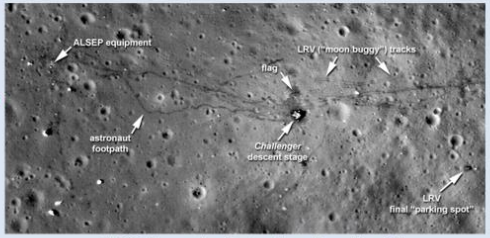


19 Node Thermal Model Used for Night Rover Energy Storage Centennial Challenge



Render Engine Used for Poster, with Over 900,000 Surface Model Polygons

Lunar Reconnaissance Orbiter (LRO) Collecting Terrain Data Since 2009



LRO Terrain Data for Apollo 17

STEM Simulation Game Provides Thermal Model with Variable Planning/Preparation, Mission Timing/Location, Rover Configuration and Power, Driving and Steering, Solar Heating, and Component Cooldown Dust Effects

181 Node SINDA Thermal Model Combined with ~7800 Reduced Polygon Surfaces TRASYS Model and LRO Terrain Data for Exploration Realism in LUROVA™

Test Your Moon Driving Skill in the LUROVA™ Simulation Game